Project Introduction

Understanding physical processes responsible for the formation and evolution of galaxies like the Milky Way is a fundamental and still unsettled problem in astrophysics. Our own Galaxy offers by far the best chance to study a galactic system in great detail regarding the formation and evolution of its structural components (disk, bulge, and halo), the conversion of gas into stars over time, and how stars' orbits change throughout the dynamical history of the system. One fundamental question in astrophysics is: when, where and how do stars form. But the properties and orbits of the stars can only be observed at present: in order to understand what happened in the Milky Way at earlier epochs, one must study the stellar fossil record. The goal of this proposal is to optimize a technique known as "chemical tagging" to unravel the fossil record of star formation in the Milky Way. "Chemical tagging" is based on the idea that stars born in a star cluster have near-identical elemental abundances. The goal is the to recognize stars as birth-siblings merely by their unique similarity in abundances, even if they are on widely dispersed orbits. This technique will shed light on how stars form, in particular, the extent to which stars form in small or massive clusters of stars and the subsequent dynamical history of stellar clusters, including their disruption, dispersal and orbital migration. In short, chemical tagging will open up entirely new ways of understanding the evolutionary history of the Milky Way. Despite the intriguing prospects of chemical tagging, previous studies of high-resolution stellar spectroscopy were limited to a few hundred stars. With these small samples, one is unlikely to sample stars from the same cluster. Fortunately, the observational landscape is rapidly changing. Recent and on-going large-scale surveys, such as GALAH, Gaia ESO and APOGEE 2 aim to observe 10^5-10^6 stars with 15-30 elements for each star. This proposal describes my plan to enable chemical tagging based on techniques that I have developed: (a) The current elemental abundances measurement has limited resolution in separating star clusters in the elemental abundances space. We demonstrated that multiple clusters share similar elemental abundances at the resolution of the observations. Thus, turning high-resolution spectra of a million stars into more precise elemental abundances is the key to the success of chemical tagging. I have developed a new spectral fitting technique that enables the fitting of 15-30 parameters simultaneously and so should deliver more precise abundances. The new technique reduces the number of models required for a synthetic library by a factor of ten million in a 19-dimensional parameter space. (b) Even in the limit where star clusters are not individually resolved through chemical tagging, we predict that different cluster mass functions (CMFs) entail strikingly different distributions for stars in elemental abundance space. By studying how clumpy the elemental abundance space is, the Milky Way CMF in the past can be statistically reconstructed. I developed a new clump search method which has shown that the Milky Way old disk population did not form clusters more massive than 30 million solar mass using the APOGEE data. As I am participating in most chemical tagging surveys, with more data soon becoming available, I plan to put more stringent limits on the history of

Unraveling the history of the Milky Way through chemical tagging

Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics

Project Management

Program Manager:

Joe Hill-kittle

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Page 1

the Milky Way with this technique. (c) Although stars are now phase-mixed in position-momentum space, information is not all lost. Gaia is currently measuring kinematics of a billion Milky Way stars and NASA's WFIRST mission is planned to launch in 2020 and will measure accurate proper motions of stars several magnitudes fainter than Gaia. I will discuss my plan to explore the connection between the chemistry and kinematics of stars, and to study how chemical tagging can benefit from the kinematic information.

Primary U.S. Work Locations and Key Partners
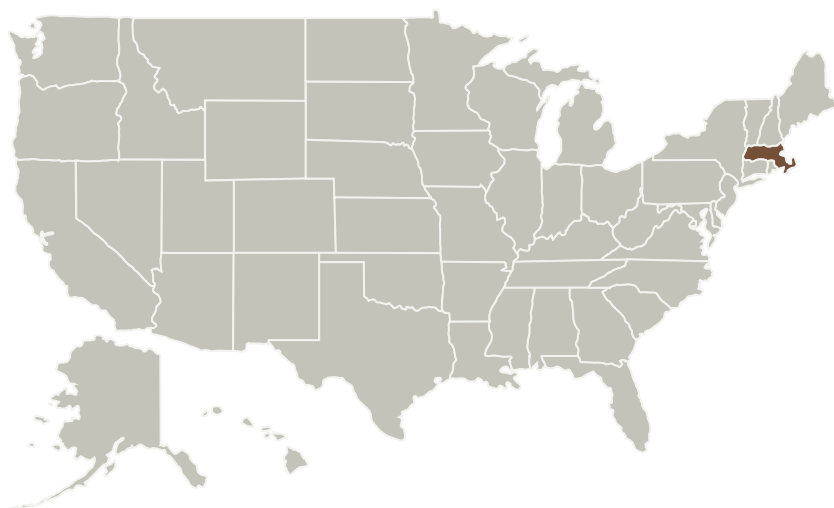
Organizations Performing Work	Role	Type	Location
Harvard University	Supporting Organization	Academia	Petersham, Massachusetts

Primary U.S. Work Locations
Massachusetts

Project Management (cont.)

Principal Investigator:

Charlie Conroy

Co-Investigators:

Karen Rizman
Yuan-sen Ting

Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
  └ TX17.4 Attitude Estimation Technologies
    └ TX17.4.3 Attitude Estimation Sensors

Target Destination

Outside the Solar System

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Page 2